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IONOSPHERIC D-REGION ELECTRON DENSITY DATA AVAILABILITY

DATA REPORT

By

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A survey of the availability of ionospheric D-region electron density data has been completed and is reported here. A table which lists 45 world locations where lower ionospheric electron density profiles have been obtained is included. The availability of electron density data is interpreted in terms of the general global distribution and in terms of both intermediate and long-path high frequency (3 to 30 MHz) Army communications channels. World maps are also included which serve to illustrate localities where D-region data have been

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20. ABSTRACT (cont)

recorded and world sections and paths where high frequency communications channels are currently active.

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INTRODUCTION

The United States Army Communications-Electronics Engineering Installation Agency (USACEEIA) provides propagation engineering services in a readily available manner to US Army field units and various other government agencies [1]. Propagation engineering services include electromagnetic systems performance analyses, electrical design of antennas, and electromagnetic wave propagation advice and predictions. USACEEIA has the perennial requirement of updating operational computer models which are used for ionospheric electromagnetic wave propagation predictions, antenna designs, and communication system analyses. Included in these models is the prediction of the 3 to 30 MHz sky-wave propagation signal attenuation. The degree of electromagnetic wave attenuation is dependent on the state of the lower ionosphere's (D and E regions) electron density structure. This data report is the first of a series directed toward the objective of improving signal attenuation predictions by updating the D- and E-region electron density data base and by incorporating the density variability into the USACEEIA computer models. Specifically, this report presents a survey of world areas from which D-region electron density data are available. It also designates the areas where general data voids exist and describes the data availability as related to the global locations which are of concern to USACEEIA.

DATA BASE

A recent, comprehensive D-region electron density data survey performed by Berry and Davis [2] served as the bulk of the data reference base used here. Additional electron density profiles, which were not included in the Berry and Davis report but are available at the Atmospheric Sciences Laboratory, comprise the remainder of the D-region data base.

Several electron density profiles were found to be incomplete in that the density plots failed to cover the entire region from 40 to 100 km. Because of the data scarcity, particularly at certain global locations, these incomplete profiles are counted as a profile. The altitude of 100 km is chosen as the preferred maximum altitude to define D-region electron density profile completeness because 100 km is the lowest altitude from which operational ground-based ionosondes electron density data can be obtained. A concurrent study survey was made to determine whether an active ionosonde station was operating in the proximity of the location where the D-region density data were measured, and to determine if the E-region ionosonde data for that measurement day have been forwarded to the United States.

DATA

The profiles of electron density as a function of altitude tabulated in this report were recorded between the period of July 1949 and September 1975 at various local times and seasons. A listing of the world locali-

ties where D-region electron densities have been measured is arranged according to descending latitude in Table 1. Also included in Table 1 are the number of electron density profiles available at each location and whether concurrent ionosonde E-region electron density data are available at the World Data Center A (WDC-A) for Ionospheric Data, located in Boulder, Colorado. The availability of E-region electron density not archived at WDC-A must be determined by contacting the English Data Center, the Japanese Data Center, and in several cases the individual ionosonde stations.

Examination of Table 1 gives a first impression of good electron density data coverage relative to latitudinal distribution. However, when these data are viewed in terms of global longitudinal distribution, as depicted in Figure 1, there is definitely a scarcity of data in certain regions of the world. The world map in Figure 1 shows the cities nearest the location at which the electron density data were recorded, and the number of profiles recorded available are inscribed in the circle adjacent to the city name.

Since most of the referenced data are not yet at the Atmospheric Sciences Laboratory, the availability of data in terms of coverage with respect to diurnal, seasonal, and solar activity has not yet been determined. Also the quality and reliability of the measurements are still undetermined.

DISCUSSION

The general availability of lower ionospheric electron density data without regard to Army high frequency (HF), 3 to 30 MHz, communication paths, is discussed first; then electron density data availability is discussed in reference to the intermediate and short distance sky-wave propagation world areas serviced by USACEEIA. These global areas are depicted in Figure 2, which was copied from reference 1. Finally, the same data are examined in terms of the long-distance propagation paths serviced by USACEEIA. Figure 3 is a world map with an abridged plot of the long-distance propagation paths and transmitter-receiver terminal points. Electron density data are reviewed in terms of their availability at the midpoint of these limited, but representative, long-distance paths.

An examination of Figure 1 provides an overall picture of the availability of lower ionospheric electron density data. Northeast Europe above 52° N latitude and particularly around 15° E longitude has fair data coverage with a total of 52 profiles. Elsewhere in Europe a data scarcity exists since only a total of 6 more profiles are available from Pruhonice, Czechoslovakia, and Baku, Russia. Several profiles have been recorded along the Mediterranean Sea area; however, the total number of useful profiles will be less than the sum of those annotated in Figure 1 since some measurements were conducted during a solar eclipse event. Africa's and India's lower ionospheres have been sampled in only the southern parts, with 15 profiles recorded at Tsuemb, South-West Africa;

TABLE 1

LOCALITIES OF D-REGION ELECTRON DENSITY MEASUREMENTS

Location	Geographic Latitude	Geographic Longitude	No. of Profiles Available	Ionosonde Data Available at WDC-A, Boulder,CO
Thule, Greenland	76.6	291.2	3	Yes
Resolute Bay, Canada	74.7	265.1	17	Yes
Tromso, Norway	69.7	19.0	11	No
Andoy, Norway	69.3	16.0	22	No
Kiruna, Sweden	67.8	20.4	2	No
Poker Flat, US	65.1	212.5	10	Yes
Oslo, Norway	60.0	11.1	17	No
Ft. Churchill, Canada	58.8	265.8	44	Yes
South Uist, Scotland	57.2	352.7	4	No
Lindau, Germany	52*	9.8*	4	No
Slough, England	51.5	359.4	9	No
Pruhonice, Czechoslovakia	50.0	15.0	2	No
Ottawa, Canada	45.4	284.1	64	Yes
Antigonish, Canada	44.9	297.7	4	Yes
Boston, US	42.6	288.5	4	Yes
Penn State Univ., US	40.8	282.1	82	No
Urbana, US	40.1	271.8	1	No
Sardegna, Italy	40.0	9.0	2	No
Boulder, US	40.0	254.7	2	Yes
Tortosia, Spain	40.0	0.0	11	No
Baku, Russia	40.0	50.0	4	No
Akita, Japan	39.7	140.1	1	No
Megara, Greece	38.0	23.6	4	No
Wallops Island, US	37.9	284.5	51	Yes
Kalamai, Greece	36.8	21.9	5	No
Crete Island, Greece	35.2	25.0	32	No
500 mi east of Tokoyo, Japan	33.9	151.2	2	No
White Sands Missile Range, US	32.2	253.5	41	Yes
Kogoshima, Japan	31.6	130.5	2	No
Eglin AFB, US	30.4	273.3	3	No
Arecibo, Puerto Rico	18.5	292.8	2	No
Thumba, India	8.6	76.9	12	No
Colombo, Ceylon	6.9	81.0	1	No
Lima, Peru	-13.0	282.0	9	Yes
Aitutaki, Cook Islands	-19*	201*	1	Yes
Tsumeb, South West Africa	-19.3	17.7	15	No
250 mi west of La Serna, Chile	-29.6	284.8	1	No
Barba, Australia	-30.5	151.5	15	No
Woomera, Australia	-31.2	136.3	3	No
Porto Alegre, Brazil	-32.2	307.8	8	Yes
Kaitaia, New Zealand	-35.0	173.0	2	No
Christchurch, New Zealand	-44.0	170.0	7	Yes
250 mi west of Chanos, Chile	-44.6	282.2	1	Yes
500 mi Southwest of Pt. Arenas, Chile	-58.5	282.0	1	No
Dumont d'Urville, Antarctica	-66.6	216.0	2	No

*Latitude and longitude are estimated.

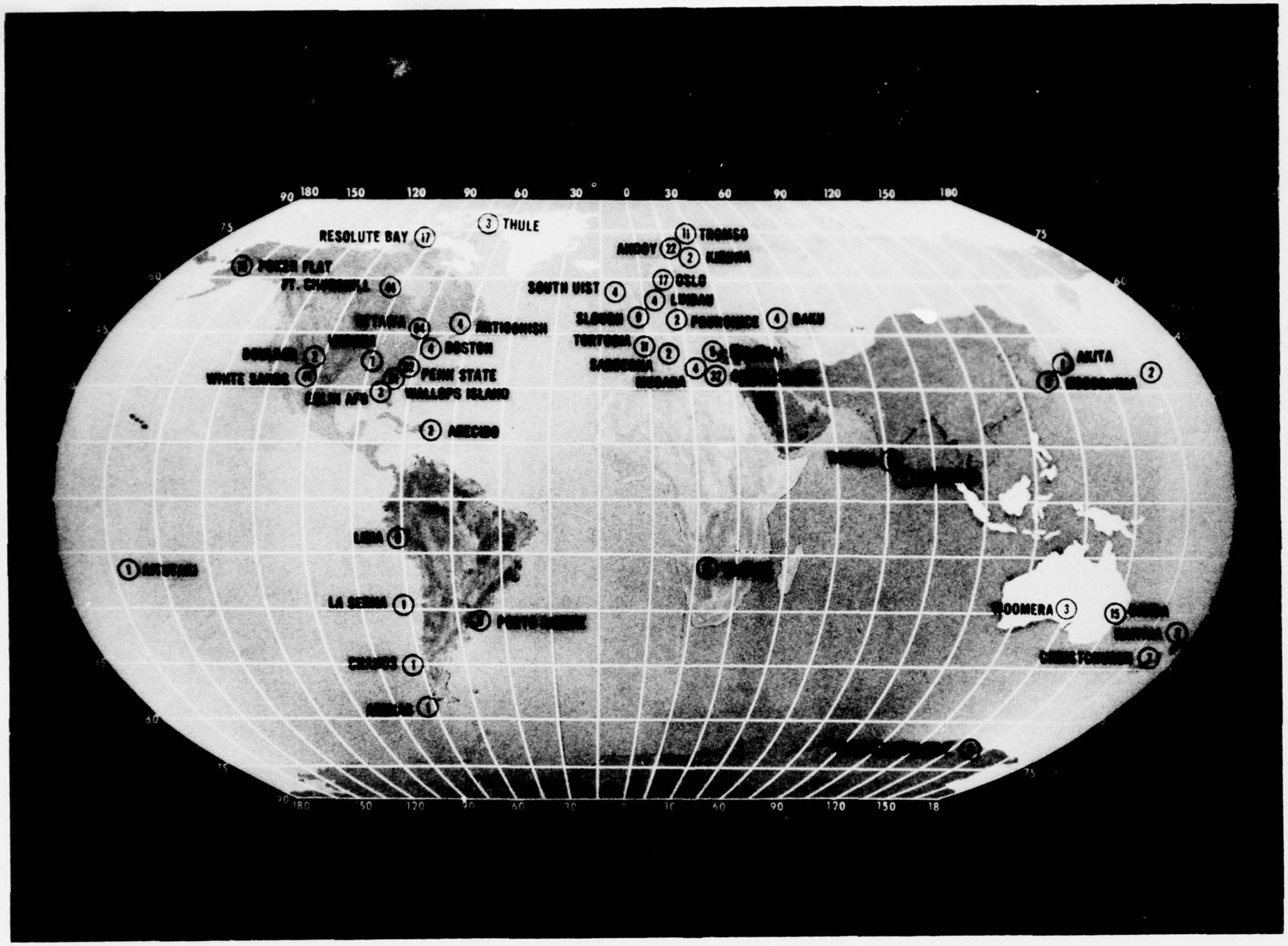

Figure 1. World map designating global localities where D-region electron densities have been measured. The number of profiles recorded at each location is inscribed inside the circles.

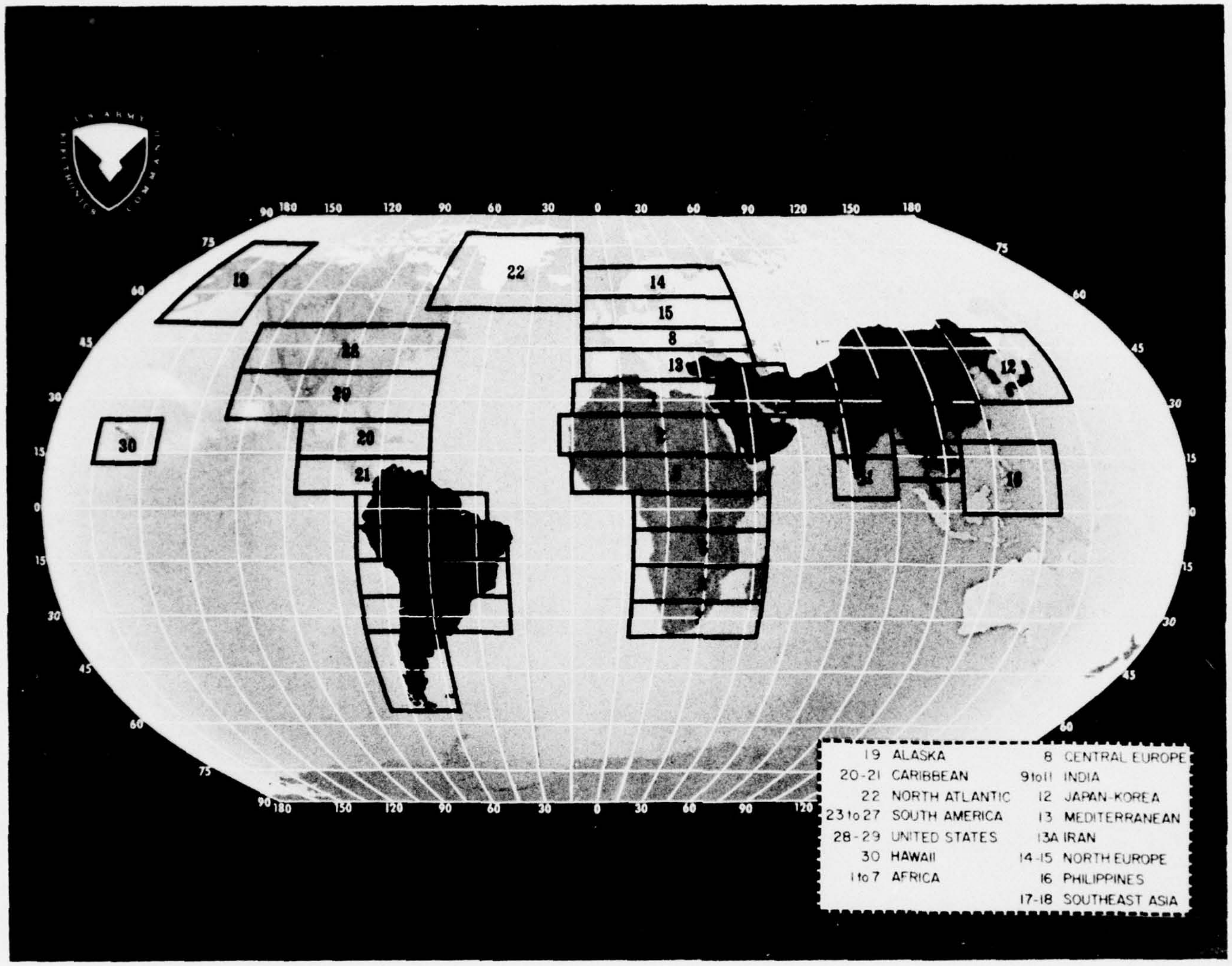

Figure 2. World map designating, by 27 rectangular regions, those areas where short and intermediate HF communications channels are utilized.

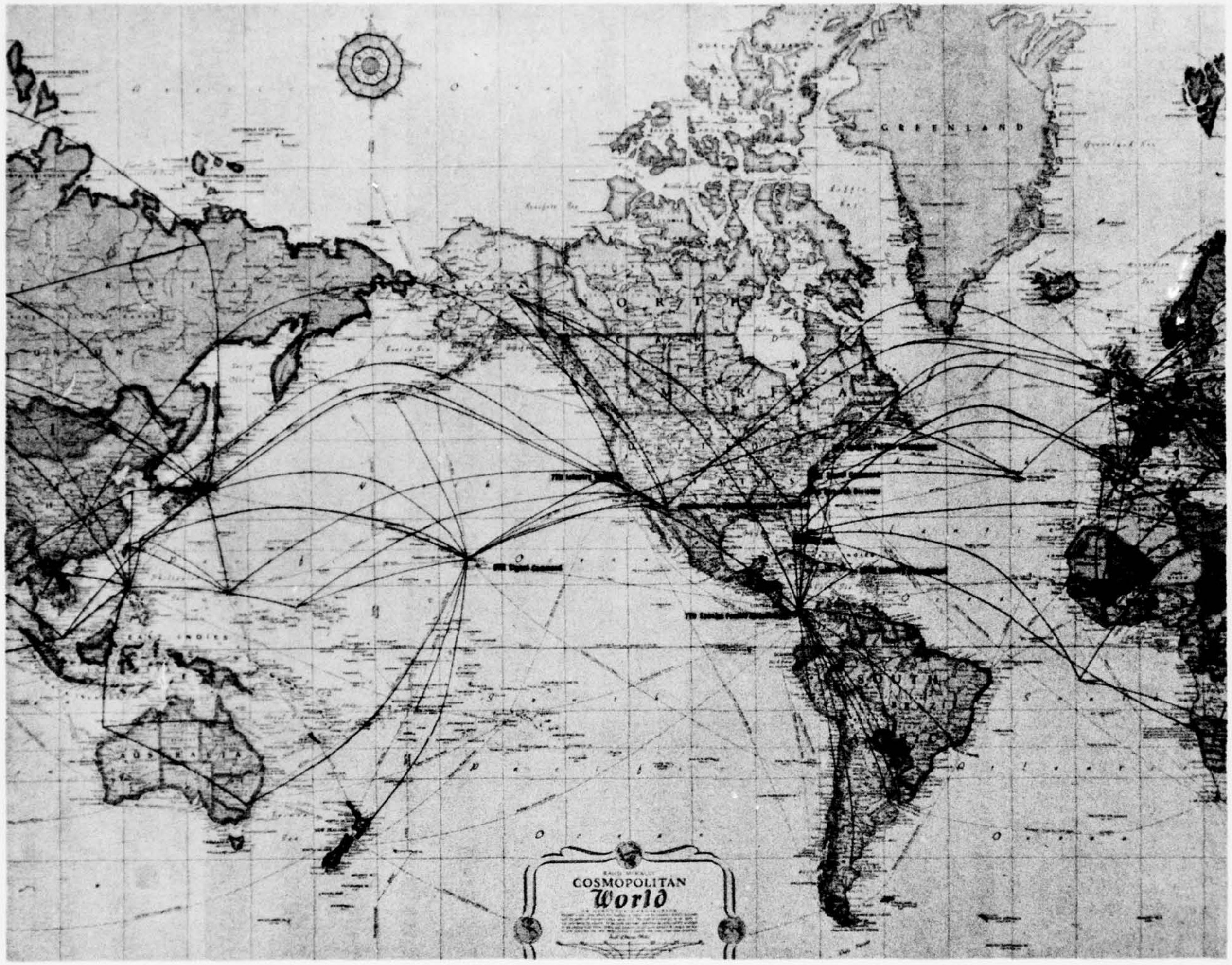

Figure 3. World map depicting a representative sample of long path HF communications channels.

12 at Thumba, India; and 1 at Colombo, Ceylon. Japan appears to have a good geographic distribution of samples, but the total number of profiles is extremely small (only 5). There are 18 profiles over Southeast Australia which should be descriptive of the D-region in that area. Four profiles are available from the New Zealand-Cook Islands vicinity. In North America, the Canadian longitudinal line of 265° E (95° W) is well sampled with 17 and 44 profiles recorded at Resolute Bay and Fort Churchill, respectively. The lower ionosphere in the eastern part of the United States should be particularly well described with the availability of at least 209 profiles (including the Ottawa and Antigonish, Canada, data). Data from Boulder, Colorado, and White Sands Missile Range, New Mexico, are available to provide some description along the 225° E (105° W) longitudinal line within the United States. There are 10 measurements recorded in Alaska which can be used to define the lower ionosphere at 65° N latitude. The three measurements from Thule, Greenland, may be combined with those from Resolute Bay to describe the 75° N D-region electron density structure. From the Caribbean Sea there are only 4 profiles recorded at Arecibo, Puerto Rico. South America's D-region has been sampled along the western coast, but data south of Lima, Peru, is extremely limited. On the Atlantic Ocean side, there are 8 profiles available from the southeastern port city of Porto Alegre, Brazil.

Lower ionosphere electron density data voids were easily determined from an inspection of Figure 1. A brief list of those general global regions devoid of D-region electron density data follows:

A block of Central Europe centered near 45° N latitude and ranging from the Bay of Biscay to the Black Sea.

Africa, except for the southwest corner.

The Middle East Turkey-Saudi Arabia-Iran area.

Russia, China, and Northern India.

Indian Ocean.

Indonesia.

Japan (limited number of samples).

Pacific Ocean, particularly along 15° N.

Western North America.

Central America.

Central and Northeastern South America.

Atlantic Ocean.

Southern and eastern Greenland.

North Pole area and Antarctica.

The availability of D-region electron density data over the short and intermediate distances shown in Figure 2 is considered now. In the African areas 1 through 7, data exist only for the Mediterranean Sea section of region 1 and for the western side of region 6. Mediterranean area 13 has data samples on its west side recorded in Italy and Spain, while its east side can be described with data from south Greece located slightly south of the area 13-area 1 boundary line. Central Europe area 8 is void of data on the west side and only has a limited amount of data, 6 profiles, in its eastern section. However, electron density profiles from adjoining areas 13 and 15 may be used to approximate the electron density structure in area 8. In area 15, North Europe, samples were found only on the western side by the cities of South Uist, Slough, and Lindau. Area 14, North Europe, appears to have an adequate sample of 35 profiles, centrally recorded in Norway and Sweden. Area 11, India, contains 12 profiles but all are located in the southernmost section. Area 13, Japan-Korea, has a very limited number of samples, 5, and all are located in the south-central section. Alaska's region 19 lower ionosphere electron structure can be defined by 10 available profiles ideally recorded in the center of the region. The lower ionosphere in area 22, the North Atlantic's west sector, may be partially defined by using the Thule data and that from Resolute Bay which is located just outside its west boundary. United States region 28 is well sampled on the eastern side, while Boulder data provides a rather limited sample in the central part of the region. United States region 29 also has apparently adequate samples on the east side and in the central section. Caribbean area 20 may be sparsely described within its southeast quadrant with the 4 profiles recorded at Arecibo. In South America there are nine electron density profiles that have been recorded in the southwest corner of region 24. Similarly, nine profiles have been recorded within region 26. For region 27, only two D-region profiles are available.

The following sectors were totally devoid of D-region electron density data: Africa 2 through 5; Africa 7; India 9 and 10; Iran; Philippines; Southeast Asia 17 and 18; Caribbean 21; South America 23 and 25; and Hawaii. A listing of additional electron density data which would be useful in defining the lower ionospheric structure within areas for which some data already exist follows:

Africa 1, measurements in the west-central section of the sector.

Africa 6, measurements in the sector's east side.

Central Europe, measurements in sector's center.

India 11, measurements in the northern section.

Japan-Korea, additional data.

Mediterranean, measurements in the eastern sector.

North Europe 14, existent profiles must be analyzed to determine additional data requirements.

North Europe 15, measurements in the east side.

Alaska, additional data to determine seasonal variability.

Caribbean 20, additional data, preferably centrally located.

North Atlantic, measurements in the central and eastern side.

South America 24, 26, 27, measurements in the central parts of these sectors.

United States 28 and 29, measurements in the western sides of these sectors.

A complete graphical representation of the long-distance HF communications links would excessively clutter a world map in certain regions of the globe; therefore, Figure 3 shows only a fraction of the total number of HF links, but those paths plotted are representative of the world distribution and particularly the heavy traffic sections. A brief description of the availability (or scarcity) of lower ionosphere electron density data along these paths now follows.

Paths connecting Alaska and United States mainland cities have some data at the terminal points, but no data exist in the path center where wave reflection occurs. These path centers occur in the vicinity of British Columbia, Canada, and the western coastal waters of Canada. Links connecting the United States western states and Panama have no data at the terminal points, except for data from White Sands Missile Range, New Mexico; and particularly no data exist at the reflection points over central Mexico. Communications traffic between eastern United States cities and Panama appear to have sufficient D-region data at the United States terminal points, but the midpoints over Cuba and Jamaica can only be sparsely defined with the profiles from Arecibo. All links between Panama and western South America have only the electron density data from Lima, Peru. No data are available for links between Panama and eastern, southern, and central South America.

The especially long paths between the United States and Europe seem to have an adequate source of data at both terminals; however, no electron density profiles have been found at the more important path center areas over the North Atlantic Ocean. Likewise, links between the United States and Africa are totally devoid of D-region data at the wave reflection points over the South Atlantic Ocean.

Communications links originating or terminating in central Africa such as those at Asmara, Ethiopia, and in the proximity of Bamako, Mali, are directed in such a way that no electron density data are available at most of the midpath points. Signal attenuation between the northwestern corner of Africa and the Middle East may be calculated by using data recorded in Italy and Greece. Likewise, signal losses between the same African corner and the vicinity of Germany may be better predicted by utilizing data recorded in Spain.

Some D-region data are available in the proximity of the midpoint between Germany and the Middle East. There also appear to be sufficient data from Norway and Sweden to adequately describe the reflection point of links connecting England and western Russia. Electron density data for paths extending across both northern and southern Russia and China are unavailable. Data are available from Thumba, India, which is situated near the midpoint of the paths connecting Malaysia and Africa. Numerous paths originate at the Island of Diego Garcia. The data from Thumba, India, and Baku, Russia, may be used to partially describe the midpath area of those links from Diego Garcia to east Russia and Bhutan. Otherwise, no electron density data are available for the other Diego Garcia links.

In the Orient, all channels connecting Malaysia, the Philippines, the Thailand vicinity, Taiwan, the Yellow Sea, Japan, and Guam are practically devoid of data. Five profiles from the Japan area provide the only D-region data in this section of the world. Wave reflection points within Australia may be characterized with ionospheric data from Woomera and Barba, Australia.

Communications traffic across the Pacific Ocean, irrespective of azimuthal direction, is generally void of D-region electron density data. Poker Flat, Alaska, data can serve to characterize the reflection point for those propagation paths which cross over the Bering Sea. Scant data are also available at the terminal points of New Zealand, Australia, and Japan.

The following list identifies global locations from where lower ionospheric electron density profiles are desirable to characterize the wave reflection point of long-distance communications paths:

The Pacific Ocean, with lesser emphasis on the Tasman Sea region.

Both the North Atlantic Ocean along the 315° E longitudinal regions and the South Atlantic Ocean particularly near Ascension Island.

Central Africa.

Gulf of Oman.

Afghanistan.

Russia and China.

British Columbia.

West Indies.

Central South America.

CONCLUSION

The above interpretation of the availability or scarcity of D-region electron density data was made before the variability of electron density at specific geographical locations was studied. Consequently, localities with high variability will obviously require more data than those with low variability. Areas with low density variability may already possess an adequate number of samples. D-region electron density variability will be the subject of the second report in this series.

This data survey is by no means an exhaustive one. Therefore, the author will appreciate references to any D-region electron measurements not included here. The author's telephone number is 915-678-1618; the author's address is:

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